Rock bolting
Uwe Wyink
Global Technical Manager Injection

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Agenda

- Motivation
- Current situation for rock support
- Alternative solution
- Customer benefit
Motivation
TOP PRIORITIES FOR GLOBAL MINING COMPANIES

Survey respondents selected workforce safety and managing capital projects as their most important priorities, followed closely by maximizing production effectiveness.

1. Ensuring workforce safety (31%)
2. Managing capital projects (25%)
3. Maximizing production effectiveness (21%)
4. Ensuring equipment operates reliably and predictably (8%)
5. Ensuring different departments work together (4%)
Challenges in tunnel development in mining

- Deeper mining results in:
  - higher rock stress
  - more difficult ground conditions in combination with moving ground
  - need for improved quality and efficiency of installed ground support
  - higher rock temperatures
  - Bigger tunnel dimensions (higher, wider)

- Requirement to improve safety
  - Keep miners away from unsupported roof and face

- Underground logistics
  - longer transport ways to tunnel headings

- Cost pressure – per linear meter tunnel
  - Higher development rate m/d
  - General lack of skilled workforce in the industry
  - Higher degree of automatization in tunnel development needed
Current challenges in tunnel development in mining

Indirect cost

- Insufficient tunnel support is leading to
  - Roadway deformation
  - Rock falls
  - Ground collapse

- Additional cost for support refurbishment
  - 3 times the cost per m for total reconstruction
  - Hindered transport in narrow tunnels
  - Higher maintenance cost for equipment
Tunnel face/roof collapse
Current situation for rock support
Rock reinforcement principles

Theory

- “Similar” principles as for a stone bridge
- Ground support reinforces the selfcarrying properties of the strata
- Rocks near open space are held/locked together
  - Sprayed applied
  - Rock bolts
  - Standing support
Existing ground support methods
Conventional

- Standing support (yielding & stiff)
  - Steel arches
  - Wood

- Sprayed concrete
  - wet & dry
  - With and without fibers

- Rockbolts
  - Mechanical anchors
  - Friction bolts
  - Grouted bolts
    - Resin cartridges
    - Cementitious cartridges
    - Cementitious grouts
Rock bolting and Cable bolting
In Mining & Tunneling

Rock bolts and Cable bolts are used extensively in ground support regimes in both hard rock and coal mines.

This ground support or rock reinforcement is seen as active support.

Rockbolts are used in combination:
- With and without mesh
- Spray applied concrete
- Steel arches

The degree of mechanization and automatization in the mines is growing.
Roof bolting theory

- Mechanical rockbolts
- Friction bolts
- Full bars
  - Point grouted
  - Fully encapsulated
- Self drilling anchors
- Cable bolts
Areas of application

<table>
<thead>
<tr>
<th>Fields of Application</th>
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<tbody>
<tr>
<td><strong>Underground</strong></td>
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<tr>
<td>Face Bolting</td>
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<td>![Face Bolting Image]</td>
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<tr>
<td>Roof and Rib Bolting</td>
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<td>![Roof and Rib Bolting Image]</td>
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Resin grouted rockbolts

- Resin cartridges
  - Various diameters
  - Various lengths
  - Various speeds

- Used for
  - Point grouting
  - Full encapsulation
Rockbolt installation (cartridges)
Rockbolt installation (cartridges)
Rockbolt installation (cartridges)
Feed rate – too fast
Rockbolt installation (cartridges)
Feed rate – too slow
Rockbolt installation (cartridges)
Mixing – too long
Rockbolt installation (cartridges)
Mixing – low rotation
Rockbolt installation (cartridges)
Rockbolt installation (cartridges)
Storing & application temperature
Rockbolt installation (cartridges)
Resin volume - borehole
Rockbolt installation (cartridges)
Resin volume - strata
Rockbolt installation (cartridges)
Resin volume – weak rock strata
Rockbolt installation
Rockbolt installation (cartridges)

Summary

- Mixing quality
  - Several mixing issues with cartridges
  - Mixing takes place in the borehole and can’t be controlled 100%
  - To much or to less bolt rotation leads to insufficient mixing
  - Correct bolt feed rate and rotation is needed
  - Bigger borehole diameter leads to finger glove effect or no mixing of resin and hardener
  - Limited shelf life of cartridges compared to pumpable resins
  - Mixing of cartridges is highly depending on the surrounding application temperature
Rockbolt installation (cement grout)
Summary
Cementitious grouts

- Enough volume = full encapsulated
- Controlled mixing outside the borehole
- Suitable for cable and long bolts
- Long setting and curing time = long re-entry time
- Wider borehole diameter = longer drilling time per meter
- Could lead to problems in water sensitive strata
Comparison

Resin Cartridges

- Short reaction time
- 100% encapsulation challenging

Grout Injection

- Long reaction time
- Fully encapsulated
Alternative solution
Requirements for a pumpable & fast reacting resin

Application
- Easy and robust mixing
- Good pumping and penetration behavior
- Thixotropic effect
- Full rockbolt encapsulation
- Adjustable to varying installation requirements

Performance
- Fast strength development
- Adequate final strength
- Comply with existing EHS regulations
MasterRoc MP 368 compact PUS for consolidation with very fast strength development

Areas of application

- **Reinforcement** of fractured coal and rock strata
- **Consolidation** of fractured rock, debris and tunnel faces
- **Sealing** against gas and water

Features and key benefits

- Very fast reacting
- High bond strength
- Fire-resistant and low reaction temperature
- For temporary and permanent application
- Works under water (no reaction with water)
- Cured material remains flexible
The needs

Resin cartridge based anchor system

Strength
- “Simple” installation
- No additional equipment needed
- Pre tensioning possible

Weakness
- Inconsistent quality due to challenging installation and mixing method
- Limited resin quantity
- Not suited for broken and friable rock

Thixotropic rock bolting resin

Features and benefits
- Low viscosity for easy mixing and consistent grout quality
- Thixotropic performance for roof bolting
- Fast strength development to provide immediate support
- Suitable for competent and broken rock strata
- Always fully encapsulated rockbolt (better load transfer)
- Existing cracks in the strata are filled and consolidated
- Automated application possible
R&D Shanghai
First pumping trials with different formulations
Rockbolt resin approval testing @ DMT Germany
Testing & results
Rockbolt pull test – bolt failure 350 kN
Testing
Fast reacting pumpable resin
Extensive testing @ Trostberg 2017/2018
MasterRoc RBA 380
Thixotropic rockbolt resin
Rockbolt installation
Fast reacting pumpable resin
Rockbolt installation
Fast reacting pumpable resin

- Mixing of pumpable resin QC check possible by operator
- Always sufficient mixing is leading to improved load transfer between bolt and strata
- Varying borehole diameter & length and cracks don’t have an impact on the encapsulation
- Optimal ratio between borehole & rockbolt diameter = fast drilling possible
- Thixotropic behavior of resin = no borehole sealing needed
- Fully encapsulated rockbolt
  - Ideal load transfer between rockbolt and strata
  - Improved corrosion protection
- Fast curing allows fast reentry time
- Curing time adjustable
- Works in temperature ranges between 5°C and 35°C
- Shelf life 12 month if stored between 0° - 30°C
- No aging of the cured product
Rockbolt installation
Varying conditions

- Rock & underground temperature
- Rock strata
  - Crack distribution
  - Surface friction
  - Strength
- Borehole diameter and length
- Rockbolt
  - Length
  - Diameter
  - Surface
Features and benefits

- Highly reactive, fire resistant thixotropic polyurea silicate injection resin for rock bolting
- Secure and precise injection due to its thixotropic properties
- Flexibility in application due to its unique thixotropic properties and long distance pumping capacity
- Increased reliability due to its full-size grouting
- Mixes easily even in low temperatures > 5°C
- High structural strength combined with flexibility
- Neither expands its volume with water, nor absorbs water
- Keep people safe during bolting due to its fast curing and strength development
One-step vs. two-step
Customer benefit
Comparison pumpable resin vs. cartridges
Rockbolt installation

installation speed 2,50 m bolt (bolt installation only, **without drilling**)

**Cartridges**
- To insert cartridges 30 sec – 10,0 min
- Bolt installation and mixing 45 sec
- Curing time fast cartridge 45 – 60 sec
- Total = 2 – 5 min

**Pumpable resin**
- Automated bolt installation 30 sec – 1 min possible
Cartridges vs. Pumpable resins corrosion
Why to change?
Cartridges vs. pumpable resin

- Increase in tunnel development rate
  - Faster reentry time
  - More efficient use of equipment
  - Less mine personal

- Higher mine productivity
  - Tunnel development = bottle neck for production

- Improved strata control
  - Less cost for maintenance
  - More efficient use of support
Rockbolt installation
Fast reacting pumpable resin

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Current challenges in tunnel development in mining

Direct cost

Times in a development cycle

- Blast hole drilling  x min
- Blast hole charging  x min
- Blasting  x min
- Scaling  x min
- Bolt drilling & installation (+mesh)  x min (>50%)
- Muck haulage  x min
- Sprayed concrete (optional secondary support)
Hello gentlemen,

I'd like to thank you once again for providing such a top notch experience detailing the advancements you've made to the Boltec product line.

The resin grout system you created will be a game changer in terms of this rig's ability to operate in ALL types of ground conditions. I've been waiting many years for this solution. You continually seek to improve what is already a stellar rig making it safer and more productive. ……..

Looking forward to continue changing the way the mining industry looks at the bolting process. You'll probably need to get more space to build more rigs!! Take care.

Bernie Whitmell
MOB Development
bernie.whitmell@vale.com
Solving your Challenges in Tunneling and Mining
Partiell vs. fully encapsulated rockbolts
Rockbolt corrosion
Field trials
Gosowong Kencana mine
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